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Mazdoor Kisan Shakti Sangathan

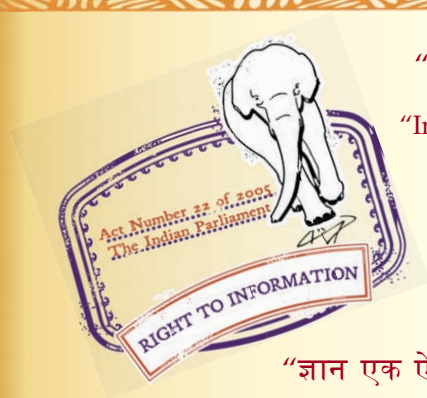
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“Step Out From the Old to the New”

IS 6916 (1973): Code of practice for fabrication welding of steel castings [MTD 12: Welding Applications]



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“Invent a New India Using Knowledge”



“ज्ञान एक ऐसा खजाना है जो कभी चुराया नहीं जा सकता है”

Bhartrhari—Nitiśatakam

“Knowledge is such a treasure which cannot be stolen”

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Indian Standard

CODE OF PRACTICE FOR FABRICATION WELDING OF STEEL CASTINGS

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**BUREAU OF INDIAN STANDARDS
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
NEW DELHI-110002**

Indian Standard

CODE OF PRACTICE FOR FABRICATION WELDING OF STEEL CASTINGS

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Indian Standard

CODE OF PRACTICE FOR FABRICATION WELDING OF STEEL CASTINGS

0. FOREWORD

0.1 This Indian Standard was adopted by the Indian Standards Institution on 27 February 1973, after the draft finalized by the Welding General Sectional Committee had been approved by the Structural and Metals Division Council.

0.2 Repair and rectification of steel castings by metal arc welding processes have been covered by IS : 5530-1969*. This standard has been prepared to specify satisfactory procedures for welding together two or more of steel castings to produce a larger cast fabrication or to form a part of a complete welded system. In all such cases the use of welding should be taken into account at the design and/or casting stages unlike the circumstances when welding according to IS : 5530-1969* would be required.

0.3 Fabrication welding principles required that proven welding procedures are used and although full details on procedure and testing are included, the requirements have been kept to the minimum necessary to ensure sound joints are produced. Manual metal arc and gas-shielded arc and submerged arc welding processes are covered for the present. Other fusion welding processes like electro slag welding will be included in due course after the industry gains experience in adopting them for the fabrication welding of steel castings.

0.4 The content of the standard follows the general pattern established in IS : 5530-1969*. Some 'typical' weld preparations have been included but each joint has to be considered in respect of its particular characteristics and it is for this reason that only guidance has been given in certain clauses. Similarly, no acceptance levels for welded joints are specified and these should be the subject of agreement between the contracting parties if an application standard does not cover them. Care is needed in the interpretation of the results of non-destructive testing bearing in mind the allowable defects which may be present in the castings in the vicinity of the welded joint.

*Code of procedure for repair and rectification of steel castings by metal arc welding process.

0.5 This standard keeps in view the manufacturing and trade practices being followed in the country in this field. Assistance has also been derived from BS : 4570 Part 2-1972 'Specification for fusion welding of steel castings, Part 2 : Fabrication welding (metric units)'.

0.6 For the purpose of deciding whether a particular requirement of this standard is complied with, the final value observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS : 2-1960*. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

1. SCOPE

1.1 This standard specifies requirements for the joining together of steel castings by fusion welding, where the components of the final fabrication are designed for that purpose or when welding is introduced at the foundry planning stage.

1.1.1 It does not cover the welding of steel castings to wrought steels, nor the surface deposition of weld metal for applications, such as corrosion resistance or hard facing.

2. TERMINOLOGY

2.1 Terms used in this standard shall have the meaning assigned to them in IS : 812-1957†.

3. CASTINGS

3.1 This standard relates to steel castings conforming to the Indian Standards listed in Table 1.

3.2 Condition of Casting — The casting prior to welding shall be sound and free from defects in the vicinity of the joint to be welded for a minimum distance equal to the thickness of the casting at the joint.

4. DISSIMILAR STEELS

4.1 Where it is necessary to join steel castings of widely different chemical composition, special consideration should be given to the choice of pre-heating temperature, welding consumables and post-weld heat treatment. In general, the pre-heating temperature should be the higher temperature recommended for the steels being welded, but exceptions to this may

*Rules for rounding off numerical values (*revised*).

†Glossary of terms relating to welding and cutting of metals.

arise, for example, when one of the components is made of austenitic manganese steel. No generalization is possible regarding the choice of welding consumables or post-weld heat treatment which will be governed by metallurgical and service considerations.

5. WELDING CONSUMABLES

5.1 Weld Metal — Electrodes, filler wire, filler wire/flux combinations, filler rod and fusible inserts shall produce weld metal that meets the following requirements.

5.1.1 Mechanical Properties — The mechanical properties of the weld metal shall generally be at least equal to the minimum in the specification for the steel castings being joined together.

In some cases it is not necessary to have matching mechanical properties and then it is permissible to use weld metal having different mechanical properties from those of the parent metal provided the manufacturer can demonstrate its suitability for the service intended after any post-weld heat treatment for the particular fabrication, or, alternatively, it is specified by the purchaser.

5.1.2 Chemical Composition — In general, weld metal shall be of similar chemical composition to that of the parent material, although in certain instances it is not essential for design purposes, nor is it always desirable for reasons of weldability or behaviour in service. In such cases it is permissible to use weld metal having a different chemical composition from that of the parent material provided the manufacturer can demonstrate its suitability for the service intended, or, alternatively, it is specified by the purchaser.

5.1.3 Electrodes, Filler Wires and Filler Rods — Details of the electrodes, filler wires and filler rods that are appropriate for various welding processes are given in Table 1.

5.1.4 Submerged-Arc Welding Consumables — Flux/electrode wire combinations shall be such that the weld metal chemical composition is similar to that of the parent metal or as otherwise agreed between the contracting parties (*see* Appendix A).

Since welding conditions have a significant effect on the weld metal chemical composition, the required composition shall be established under test conditions similar to those to be used on the actual fabrication. Particular care shall be taken controlling welding conditions to ensure consistent weld metal composition, especially where the alloying elements are contained in the flux.

TABLE 1 RECOMMENDED METHODS OF WELD PREPARATION, SELECTION OF WELDING CONSUMABLES, PRE- AND POST-WELD TREATMENT TEMPERATURES FOR DIFFERENT INDIAN STANDARD GRADES OR STEEL CASTINGS

(Clauses 3.1, 5.1.3, 13.2, 13.2.1 and 15.1)

Sl. No.	STEEL TYPE	SPECIFICATION AND GRADE	METHOD OF WELD PREPARATION (see 7.2)	RECOMMENDATIONS FOR				
				Electrodes and Filler Material			Minimum Preheating Temperature (see 13) °C	Post-Weld Heat Treatment Temperature (see 15) °C
				Manual metal arc welding	Gas shielded welding	Submerged arc welding		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
1.	Low-carbon	IS : 1030, Grade 3 IS : 2856, Grade CSW-C20 IS : 2985 IS : 2986 IS : 4491, Grades 1 & 2 IS : 4899, Grade 1	a, b, c or d	IS : 814, Groups 1 & 2	IS : 6419, S-1, S-3, S-4	IS : 3613	None	580-650 (Note 1)
2.	0.25 to 0.35 C	IS : 1030, Grade 2 IS : 2856, Grade CSW-C25	a, b, c or d	IS : 814, Group 2	IS : 6419, S-2	IS : 3613	Note 2	600-650 (Note 3)
3.	0.35 to 0.45 C	IS : 1030, Grade 1	a, b, c or d	IS : 814, Group 2, (Note 4)	IS : 6419, S-2 (Note 4)	IS : 3613	150	600-650 (Note 3)
4.	C-Mn	IS : 3038, Grade 2 IS : 4899, Grade 1	a, b, c or d	IS : 1395	Note 5	Note 5	150	630-680 (Note 3)
5.	1.5 Mn	IS : 3038, Grade 1 IS : 2708, Grades 1 & 2	a, b, c or d (Note 6)	IS : 814, Group 2	IS : 6419, S-2 (Note 4)	IS : 3613 (Note 4)	150 (Note 7)	600-650 (Note 8)

6.	1.6 Mn	IS : 2708, Grade 3	a, b, c or d (Note 6)	IS : 814, Group 2	Note 4	IS : 3613 (Note 4)	200	600-650 (Note 8)
7.	Austenitic manganese	IS : 276	a, c, or d	IS : 5206 or any suitable austenitic electrode with or without a facing of austenitic manganese steel		Note 5	Note 9	None
8.	High tensile	IS : 2644, Grades 1 & 2	a, b, c or d (Note 10)	Note 5	Note 5	Note 5	200 (Note 11)	600-650 (Notes 8 & 12)
9.	1.25 Cr-Mo	IS : 3038, Grade 5	a, b, c or d (Note 10)	IS : 1395, Group C	IS : 6560, SLA-3	Note 5	250	630-680
10.	2.25 Cr-Mo	IS : 3038, Grade 5	a, b, c or d (Note 11)	IS : 1395, Group D	IS : 6560, SLA-4	Note 5	250	680-710 (Note 12)
11.	5 Cr-Mo & 9	IS : 3038, Grades 6 & 7	a, c or d (Note 10)	IS : 1395, (Note 5)	IS : 6560, SLA-5	Note 5	300	650-720 (Note 13)
12.	9 Cr-Mo	IS : 3038, Grade 7	a, c or d (Note 10)	Note 5	IS : 5856, S-B02, MoL, S-B02 Mo (Note 14)	Note 5	300	650-720 (Note 13)
13.	Cr-Mo-V	IS : 3038, Grade 3	a or c (Note 10)	Notes 5 & 15	IS : 6560 SLA-4 (Note 15)	Notes 5 & 15	250	680-710 (Notes 15 & 16)
14.	13 Cr & 13 Cr-Mo	IS : 3444, Grades 1, 2 & 3	a or c (Note 10)	Note 5	IS : 5856, S-B01Nb, S-B04, S-B05Nb, S-B02Mo (Notes 14 & 17)	Note 5	300	680-750 (Note 18)

(Continued)

TABLE 1 RECOMMENDED METHODS OF WELD PREPARATION, SELECTION OF WELDING CONSUMABLES, PRE- AND POST-WELD TREATMENT TEMPERATURES FOR DIFFERENT INDIAN STANDARD GRADES OR STEEL CASTINGS—Contd

SL No.	STEEL TYPE	SPECIFICATION AND GRADE	METHOD OF WELD PREPARATION (see 7.2)	RECOMMENDATIONS FOR				
				Electrodes and Filler Material			Minimum Preheating Temperature (see 13) °C	Post-Weld Heat Treatment Temperature (see 15) °C
				Manual metal arc welding	Gas shielded welding	Submerged arc welding		
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
15.	18 Cr 8 Ni	IS : 3444, Grade 6	a, c or d (Note 6)	IS : 5206 (Note 14) MA01, MB01L	IS : 5856, S-B01, S-B01L, S-B01Nb (Note 19)	Notes 5 & 19	None	1 000-1 100 (Note 20)
16.	18 Cr 8 Ni/ Nb/Ti	IS : 3444, Grades 6, 7, 8 & 9	a, c or d (Note 6)	IS : 5206 MB01Nb	IS : 5856, S-B01Nb	Note 5	None	Note 16
17.	18 Cr 8 Ni Mo	IS : 3444, Grade 11	a, c or d (Note 6)	Note 5			None	Note 16
18.	18 Cr 10 Ni 2.5 Mo			IS : 5206, MB02Mo, MB02MoL, MB02MoNb	IS : 5856, S-B02MoNb, S-B02MoL	Note 5		
19.	18 Cr 10 Ni 2.5 Mo-Nb							
20.	18 Cr 10 Ni 3.5 Mo	IS : 3444, Grade 10	a, c or d (Note 6)	IS : 5206, MB03Mo	IS : 5856, S-B02Mo, S-B02MoL	Note 5	None	1 000-1 150 (Rapid cool)

21.	Cr and Cr Ni	IS : 4522	a, b, c or d (Note 6)	IS : 5206, (Notes 5 & 14)	Notes 14 & 17	Note 5	300 for Grade 1 and none for others	680-750 for Grade 1 and none for others (Note 13)
22.	0.4-0.5 C	IS : 2701, Grade 1	a, b, c or d	IS : 814, Group 2, (Note 21)	IS : 6419 S-2 (Note 21)	IS : 3613 (Note 5)	200	600-650 (Note 13)
23.	Low carbon (Case car- burizing)	IS : 4898	a, b, c or d	Note 5	Note 5	Note 5	None	580-650 (Note 13)
24.	3 Ni (Case carburizing)	IS : 4898	a, b, c or d (Note 10)	Note 5	Note 5	Note 5	250	580-620 (Note 8)
25.	3½ Ni-Cr-Mo (Case car- burizing)	IS : 4898	a, b, c or d (Note 10)	Note 5	Note 5	Note 5	250	600-650
26.	Low-carbon (Low tem- perature)	IS : 4899, Grade 1	a, b, c or d	IS : 814, Group 2 (Note 22)	Note 5	IS : 3613	None	600-650 (Note 8)
27.	C-Mo (Low tem- perature)	IS : 4899, Grade 2	a, b, c or d	IS : 1395	Note 5	Note 5	150	630-680
28.	3.5 Ni (Low tem- perature)	IS : 4899, Grade 3	a, b, c or d (Note 10)	IS : 1395	Note 5	Note 5	250	580-620

NOTE 1 — Due to the excellent weldability of these steels, while stress relieving at 580-650°C after welding is desirable, it is not always essential. For some applications a range of 580-620°C is specified.

NOTE 2 — If the section thickness or configuration is such that preheating is necessary, the preheating temperature shall be 100°C minimum.

NOTE 3 — In special cases, for example, if the carbon exceeds 0.35 percent or with castings having rapid changes in section and subject to a high degree of internal stress, it is recommended that an immediate post-heating of 600-650°C, followed by air cooling, be applied.

(Continued)

TABLE 1 RECOMMENDED METHODS OF WELD-PREPARATION, SELECTION OF WELDING CONSUMABLES, PRE- AND POST-WELD TREATMENT TEMPERATURES FOR DIFFERENT INDIAN STANDARD GRADES OR STEEL CASTINGS — Contd

NOTE 4 — The tensile strength of these filler materials is rather low compared with that of the cast steel but the yield stress is satisfactory.

NOTE 5 — No suitable electrode or filler wire complying with an Indian Standard is available, although suitable types are manufactured and marketed under various trade names.

NOTE 6 — If any method except (a) is used, it shall be followed by grinding.

NOTE 7 — The actual preheat temperature will depend on the chemical composition. The value quoted is for analysis which are towards the upper end of the composition range. The application of a carbon equivalent formula may be helpful in determining preheating temperatures for this grade of steel.

NOTE 8 — A lower post-weld heat treatment may be necessary for certain hardened and tempered castings in order to maintain the specified tensile strength, but if this is done, the time at the heat treatment temperature may have to be extended to ensure adequate stress relief.

NOTE 9 — This steel shall not be preheated and the interpass temperature shall not be allowed to exceed 200°C.

NOTE 10 — If any method except (a) is used, the casting shall be preheated and the preparation shall be followed by grinding.

NOTE 11 — Depends on composition of steel; higher temperatures may be necessary.

NOTE 12 — For heavy sections and steels of certain compositions Note 13 may apply.

NOTE 13 — Extreme care is needed when welding these steels which require immediate post-weld heat treatment to minimize the risk of cracking.

NOTE 14 — These filler materials have non-matching compositions and/or properties to the parent casting.

NOTE 15 — Welds made using vanadium bearing electrodes are susceptible to carbide embrittlement.

NOTE 16 — Welds in this material shall be ground at the toes, before post-weld heat treatment, if any.

NOTE 17 — In the case of steel castings to IS : 3038-1965, Grade 3 and IS : 3444-1966, Grade 1, the filler wires specified are not suitable for those parts of castings subject to abrasion. In the case of these the following considerations also apply:

- a) In all cases, particularly when it is intended to use austenitic filler wires to minimize the risk of cracking, reference should first be made to the service requirements of the casting for hardness, corrosion and abrasion resistance, fatigue and tensile properties and appearance.
- b) A 13-percent chromium filler wire may be used provided a satisfactory weld can be made.

NOTE 18 — Extreme care is needed when welding this steel which requires immediate post-weld heat treatment to avoid cracking. When certain austenitic steel electrodes or filler metals have been used it may not be essential to apply any post-weld heat treatment.

NOTE 19 — Weld before final heat treatment.

NOTE 20 — In the case of high Cr and Cr Ni steel castings during post-weld heat treatment the temper brittleness range (540-650°C) is to be avoided. Hold the casting within the prescribed range for not less than one hour per 25 mm of thickness. Quench all parts of the casting uniformly and as rapidly as possible. Material not stabilized with columbium or titanium should be cooled through the range of (920-540) in not more than three minutes. The rapid-cooling should be continued to below 425°C. Slower cooling rates may be just as satisfactory for some composition of the material and conditions of service.

NOTE 21 — Should not be used for surfaces subject to abrasion.

NOTE 22 — Care should be taken to ensure that the low temperature weld metal properties are appropriate for service conditions.

NOTE 23 — The following standards are referred to in Table 1 and the notes above.

- IS : 276-1969 Specification for austenitic manganese steel castings (*second revision*)
- IS : 814-1970 Specification for covered electrodes for metal arc welding of structural steel (*third revision*) (*Since revised and split into various parts*).
- IS : 1030-1962 Specification for steel castings for general engineering purposes (*revised*) (*Since revised*).
- IS : 1395-1964 Specification for molybdenum and chromium molybdenum low alloy steel electrodes for metal-arc welding (*revised*) (*Since revised*).
- IS : 2644-1969 Specification for high tensile steel castings (*first revision*)
- IS : 2701-1964 Specification for brush, carriage washing (without handle)
- IS : 2708-1964 Specification for 1.5 percent manganese steel castings (*Since revised*).
- IS : 2856-1964 Specification for carbon steel castings suitable for high temperature service (fusion welding quality) (*Since revised*).
- IS : 2985-1964 Specification for steel castings for ship's structure (*Since revised*).
- IS : 2986-1964 Specification for steel castings for marine engines and boilers
- IS : 3038-1965 Specification for alloy steel castings for pressure containing parts suitable for high temperature service (*Since revised*).
- IS : 3444-1966 Specification for corrosion resistant steel castings
- IS : 3613-1966 Specification for acceptance tests for wire flux combinations for submerged-arc welding equipment (*Since revised*).
- IS : 4491-1968 Specification for steel castings of high magnetic permeability
- IS : 4522-1968 Specification for heat resistant alloy steel castings
- IS : 4898-1968 Specification for steel castings for case carburizing
- IS : 4899-1968 Specification for ferritic steel castings for use at low temperatures
- IS : 5206-1969 Specification for corrosion-resisting chromium and chromium-nickel steel covered electrodes for manual metal arc welding.

5.2 Storage and Handling — Electrodes, filler wires and rods, and fluxes shall be stored, handled and used in accordance with the manufacturer's recommendations. In certain cases re-drying or re-baking of electrodes above the minimum temperature recommended by the manufacturer may be advantageous, but the maximum permissible temperature for a particular electrode should be ascertained from the manufacturer. Electrodes, filler wires and rods, and fluxes that show signs of damage or deterioration shall not be used.

5.3 Shielding and Purging Gases — When a gas or gas mixture is used it shall be of the following quality, as appropriate:

- a) *Argon* — The gas shall comply with the requirements of IS : 5760-1970*.
- b) *Carbon Dioxide* — The gas shall comply with the requirements of IS : 307-1966†.
- c) *Gas Mixtures* — The use of gas mixtures is permissible provided that they have proved to be satisfactory as a result of procedure qualification tests.

When a gas mixture is used which has specified additions the variation of such additions shall not exceed ± 10 percent of stated value.

Moisture content shall correspond to a dew point of -30°C or lower.

6. EQUIPMENT

6.1 Welding plant, instruments, cables and accessories shall comply with the requirements of the appropriate Indian Standard where available. Their capacity shall be adequate for the welding procedure proposed and subsequently to be qualified. The contractor shall maintain all welding plant and ancillary equipment in good working order.

6.1.1 All electrical equipment used in connection with the welding operation shall be adequately earthed.

6.2 Adequate means of measuring current shall be available either as part of the welding plant or by the provision of a portable ammeter. In the case of automatic and semi-automatic welding, means shall be provided for measuring accurately the arc voltage since this exerts considerable influence on the form, composition and soundness (that is, porosity) of the weld.

6.3 When using a gas-shielded welding process, means of measuring the gas flow shall be provided.

*Specification for compressed argon.

†Specification for carbon dioxide (second revision).

6.4 Where necessary, staging and protection from the weather shall be provided to enable the welding operation to be performed properly. This is particularly necessary when using a gas-shielded welding process.

7. PREPARATION FOR WELDING

7.1 Types of Weld Preparation — In general, these should follow the same shapes as for wrought materials, based on thickness and access for welding. Some typical preparations are given in Fig. 1 and 2.

Joint should take the form of butt welds between equal thickness sections where possible, in order to facilitate welding and inspection.

7.2 Methods of Preparation — The following methods may be used, but the final method of preparation shall be determined by the configuration required:

- a) Mechanical methods, including machining;
- b) Flame gouging;
- c) Carbon-arc or metal-arc gouging in combination with air or oxygen or other suitable gases; and
- d) Powder washing.

The suitability of these methods for specific steels is given in Table 1.

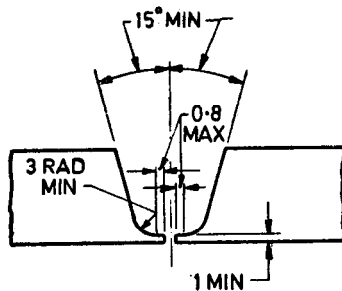
NOTE — Sound welding is more likely to be achieved if preparation for welding is taken into account at the design and foundry stages. In some instances the casting can be provided with a preparation without the need for further mechanical or thermal treatment, other than shot blasting.

7.3 Fusion Faces — The foundation for welding shall be good and the exposed material shall be sound and free from all foreign matter.

When the service conditions demand, it may be necessary to apply suitable non-destructive testing to prove that the fusion faces and adjacent areas are acceptable to the contracting parties. In certain cases, filamentary shrinkage may be sealed-off by suitable means, subject to agreement between the contracting parties (*see* Appendix A).

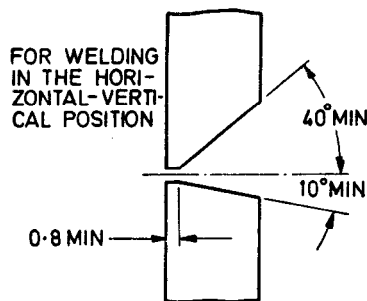
8. BACKING STRIPS AND BARS

8.1 Backing Strips (Permanent) — In certain circumstances of access, to ensure full penetration with a single V or U preparation, a backing strip may be used, in which case it shall be of a type agreed to between the contracting parties. Careful consideration shall be given to the method of attaching backing strips, for example, intermittent welding along the edges to attach it to one or both members is not permissible where fatigue conditions operate in service. Backing strips shall not be attached by welding all round their perimeter in order to minimize the risk of basal cracking (*see* Appendix A).



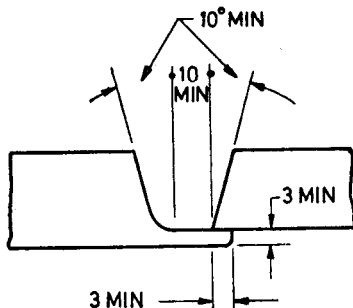
(a)

NOTE — The dimension for the gap depends on the welding process being used and whether a fusible insert is to be employed.

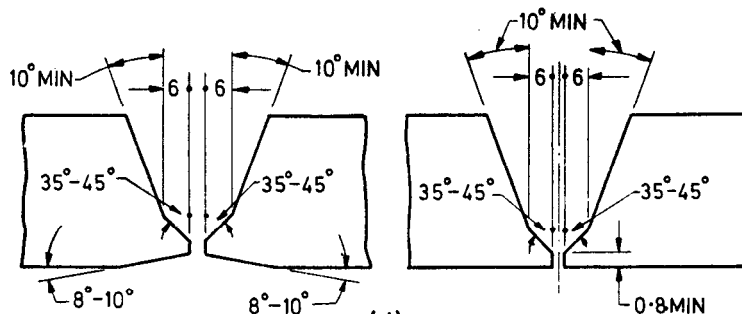


(b)

NOTE — The dimension for the gap depends on the welding process being used and whether a fusible insert is to be employed.



(c)

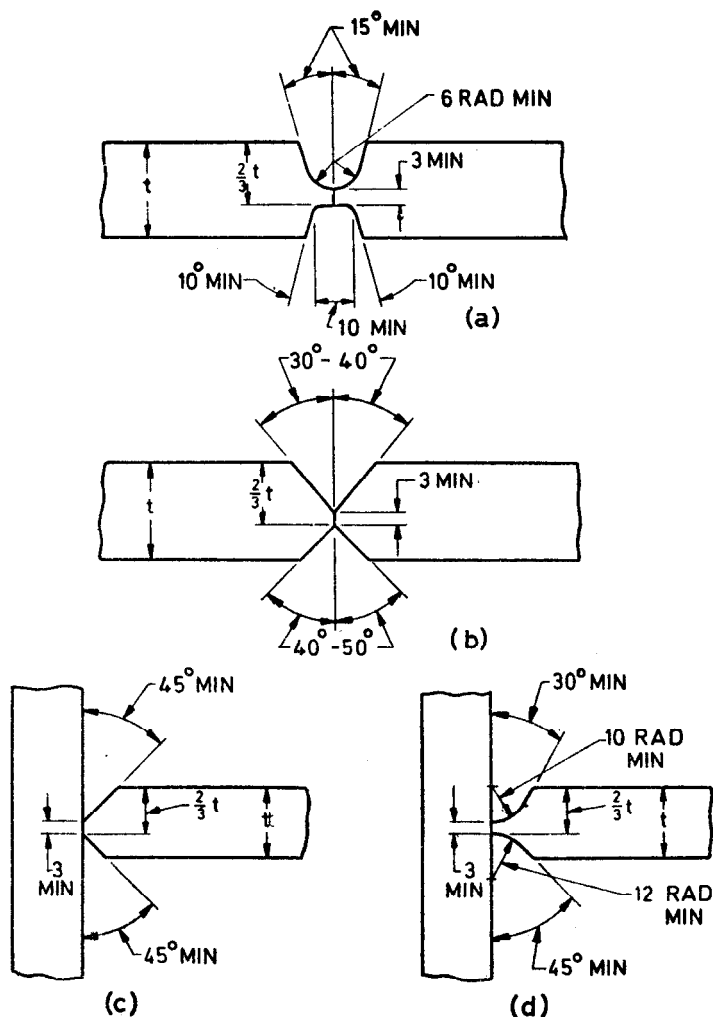


(d)

NOTE — Each preparation may be used with or without a backing strip, the dimension for the gap depends on the welding process being used.

All dimensions in millimetres.

FIG. 1 TYPICAL JOINT PREPARATIONS FOR WELDING FROM ONE SIDE



NOTE — Certain welding procedures achieve full penetration without back gouging, but where this cannot be proved, the back of the first run should be gouged out by suitable means to clean sound metal before welding is started on the gouged outside.

All dimensions in millimetres.

FIG. 2 TYPICAL JOINT PREPARATIONS FOR WELDING FROM BOTH SIDES

8.2 Metal Backing Bars (Temporary) — When a metal backing bar is used it shall be of similar chemical composition to that of the casting or it shall be a carbon steel up to 0.26 percent carbon provided that the sulphur and phosphorus contents do not exceed 0.04 percent each. Backing bars shall not be welded all round their perimeter in order to minimize the risk of basal cracking.

8.3 Copper Backing Bars — Copper backing bars shall only be used by agreement between the contracting parties since there is a danger of copper pick-up in the weld metal (*see* Appendix A).

8.4 Non-metal Backing Bars — Non-metal backing bars shall be of non-combustible materials and shall be completely removed after completion of welding.

9. ASSEMBLY

9.1 To maintain the required alignment and gap where used, during welding, the parts to be welded shall be securely held in position by mechanical means, welded-on bridge pieces, or by tack welding. When sufficient weld metal has been deposited to make the fabrication self-supporting, bridge pieces or mechanical clamps shall be removed and potential distortion controlled by welding sequence rather than by mechanical restraint.

NOTE — Cracking can result if bridge-pieces or mechanical clamps remain in position during completion of the weld.

9.2 Preheating, as required by 13, shall be applied and maintained during tack welding and the welding-on of bridge pieces or other attachments.

9.3 Electrodes, filler rods or filler wires used for tack welding shall be of the same type and class and of a size not larger than those used for completing the first run of weld metal.

9.4 Particular attention shall be paid to the quality of tack welds which shall be made by qualified welders. The throat thickness of tack welds made with filler metal shall be similar to that of the initial root run. Where necessary, the extremities of these tack welds shall be dressed by grinding or chipping to facilitate proper fusion when they are incorporated in the root run. Any cracked tack weld made with or without filler metal shall be completely removed and retack-welded.

9.5 Care shall be taken when removing welded-on bridge pieces. *Under no circumstances shall they be knocked off*, but removed by hack saw or disc grinder at a point close to the surface of the casting. The remnants of the bridge pieces and attaching weld shall be removed by grinding or filing until the surface contour of the casting is restored. The area embracing that exposed

by the welds that attached the bridge pieces shall be examined by non-destructive means to determine whether rectification is required by grinding or by welding. All welded-on bridge pieces shall be removed before applying any post-weld heat treatment, which shall include the area occupied by the bridge pieces.

10. DISTORTION

10.1 The welding procedure and production sequence shall be chosen so that distortion is minimized; this is particularly important when finished machined castings are to be welded.

11. ARC STRIKES

11.1 Contact of the electrode or of the non-insulated parts of electrode holders with the casting shall be avoided. A striking plate shall be used for striking the arc or cleaning the tip of an electrode and not the casting.

NOTE — It is recommended that electrode holders be of the fully insulated type.

11.2 Except when welding low carbon steel castings, an area on each side of and adjacent to the weld shall be protected by suitable insulating means, so as to avoid arcing on the casting surface. Welding return leads shall be connected to the work by some means that prevents damage by sparking.

12. INTER-RUN CLEANING

12.1 Each run of weld metal shall be cleaned before a further run is applied, particular attention being paid to the junctions between the weld metal and the fusion faces. Visible defects, such as cracks, cavities and other deposition faults shall be removed before deposition of further weld metal.

13. PREHEATING AND INTERPASS TEMPERATURES

13.1 Definitions

13.1.1 Preheating temperature is the temperature of the parent metal in the welding region immediately prior to the absorption of any heat from the welding process and is applicable to the first and all subsequent runs.

13.1.2 Interpass temperature, in a multi-run weld, is the temperature of a section of deposited weld metal and adjacent parent metal immediately prior to welding again at that section.

13.2 Preheating — No thermal cutting or welding shall be carried out when the temperature of the castings is below 15°C. Recommendations for preheating are given in Table 1 and during cutting or welding the actual preheating temperature prescribed shall be maintained in the region of the weld.

13.2.1 If it is not possible to preheat the entire fabrication, either because of its size or because the extent of the welding required is such that the fabrication will fall below the appropriate temperature specified in Table 1 before the completion of welding then local preheating shall be used over an area on each side of the weld having a width of at least three times the thickness of the material. Whichever method is used, it is preferable to preheat the fabrication to a temperature slightly higher than the minimum given in Table 1 so that either the weld is completed before the temperature falls below the value stated or the number of reheatings required is kept to a minimum.

14. COOLING AFTER WELDING

14.1 In general, low carbon steel and austenitic steel fabrications may be cooled naturally without precautions. In the case of other steels care shall be taken to ensure slow even cooling.

15. POST-WELD HEAT TREATMENT

15.1 The object of post-weld heat treatment is to reduce stresses due to welding, to reduce hardening, to soften weld-hardened zones or to achieve specified properties. Recommendations for post-weld heat treatment are given in Table 1.

15.2 For many steels, the heat treatment of the fabrication shall be considered in relation to any general heat treatment to be applied to the component castings to provide specific properties. When such general heat treatment has been applied before welding is done, it may be necessary to repeat the treatment after welding.

15.3 The heat treatment may be of one of the following forms:

- a) An immediate stress relief, where the fabrication is stress relieved before its temperature falls below the minimum preheating temperature.
- b) A final heat treatment of the fabrication carried out before its temperature falls below the minimum preheating temperature.
- c) A stress relieving, annealing, normalizing or quenching and tempering heat treatment carried out some time after the fabrication has cooled from the welding temperature. When the fabrication has been allowed to go cold after welding, the temperature of the furnace shall not be above 300°C at the time of inserting the fabrication.

15.4 Heat treatment shall be carried out by one of the following methods, care being taken to ensure that the minimum stipulated temperature is achieved uniformly through the thickness of the fabrication:

- a) Heating in a stationary industrial furnace; and
- b) Local heating using a portable muffle furnace, or induction coils, or resistance heaters.

15.4.1 Manually-operated gas torches shall not be used.

15.5 Where other methods of heating are the accepted practice in certain industries these may be used by agreement between the contracting parties but consideration should be given to the metallurgical effects of such methods. The foregoing methods are, however, preferable (*see* Appendix A).

15.6 The heating and cooling rates shall be appropriate to the material, geometry and thickness which would be verified by the welding procedure tests.

16. MEASUREMENT OF TEMPERATURE

16.1 General — Preheating, interpass and post-weld heat treatment temperatures, where applicable, shall be checked during the period of their application and all post-weld heat treatment conditions shall be noted in the form of written records which shall be made available on request.

16.2 Preheating and Interpass Temperatures — Preheating and interpass temperatures shall be checked by using thermocouples, pyrometers or by temperature indicating paints or crayons when they are compatible with the casting material.

NOTE — Temperature indicating paints will not indicate by how much the minimum temperature is exceeded. Some types of paint will not show, once the temperature has been reached, that this temperature is being maintained. In these cases the paint has to be re-applied if continued temperature observations are to be made.

16.2.1 When preheating is being applied by flame to the surface of the casting being welded, the flame shall be removed for at least two minutes before the temperature is checked.

16.3 Post-Weld Heat Treatment Temperature — Thermocouples shall be used for recording post-weld furnace heat treatment temperatures.

16.3.1 For local treatment separately attached thermocouples shall be used.

NOTE — Thermocouple junctions and wires should be protected from flame impingement. To prevent direct radiation from the heating elements on the hot junction when electrical resistance heating is used, thermocouples should be covered with a protective wrapping.

17. ALTERNATIVE METHODS OF STRESS RELIEF

17.1 When fabrications cannot receive planned thermal stress relief, alternative methods of stress relief may only be used by prior agreement between the contracting parties (*see* Appendix A).

18. DRESSING

18.1 Dressing of the weld area may be necessary for any of the following reasons:

- a) To facilitate non-destructive testing;
- b) To remove notches, that would impair fatigue properties;
- c) For service in corrosive environments; and
- d) To minimize the risk of stress relief cracking in the case of Cr-Mo-V steel and stabilized austenitic stainless steels.

The method of dressing shall be one of those given as (a), (b) and (c) in 7.2. When a thermal process is used the requirements and precautions in 7 to 13 shall apply. In such cases careful grinding shall follow the thermal dressing. Any post-weld heat treatment shall follow this grinding. Grinding wheels for use on austenitic stainless steels shall be of the 'iron free' type and shall have been used only on such steels.

19. INSPECTION OF COMPLETED WELDS

19.1 The method or combination of methods and frequency of inspection with the standard of acceptance for completed welds shall be as specified in the standard for particular application or as agreed to between the contracting parties at the time of the enquiry and/or order (*see* Appendix A).

20. RECTIFICATION OF FAULTY WELDS

20.1 When welds fail to comply wholly or partly with the standard of acceptance derived in accordance with 19, all unacceptable defects shall be removed. Preparation and re-welding shall be in accordance with the requirements of IS : 5530-1969*.

20.2 A repaired weld shall be subjected, as a minimum requirement, to the same testing and inspection requirements as the original weld.

21. PROCEDURE QUALIFICATION

21.1 **General** — The object of procedure qualification tests is to prove the feasibility of a manufacturer's particular welding procedure as distinct from the ability of an individual welder to deposit sound weld metal.

*Code of procedure for repair and rectification of steel castings by metal arc welding process.

21.1.1 A manufacturer shall be exempt from making procedure qualification tests in accordance with this clause when he can show that for the previous three years he has successfully undertaken welding in the fabrication of steel castings in compliance with satisfactory welding procedures in respect of welding process, type of steel, filler metal and approximate thickness. A manufacturer shall also be exempt when he can show that he has previously made successful procedure tests of the type required.

21.1.2 In other cases, welding procedure qualification tests shall be carried out before a manufacturer can be permitted to weld castings in accordance with this standard. For each of the steels in Table 1 for which approval is required, the welding procedures shall specify the details given in **21.2**, including the operational ranges for each relevant feature. These welding procedures shall be submitted for approval by the purchaser if requested.

21.1.3 Separate procedure qualification tests are not necessarily required for each type of steel where proof of satisfactory performance does not exist. Where welding procedures are similar with respect to welding process, welding position, preheating, post-weld heat treatment, electrodes, filler material, flux or shielding gas, then one welding procedure qualification test may be sufficient. When separate procedure tests are required this shall be stated in the enquiry and/or order.

21.1.4 It is recommended that welding procedure qualification tests carried out in accordance with this standard and witnessed by an independent inspecting authority should be accepted by other inspecting authorities provided that all the provisions have been fulfilled.

21.2 Procedure Test Records — The records of the procedure qualification tests shall specifically include the following details:

- a) Type of steel;
- b) Welding process;
- c) Joint preparation;
- d) Method of preparation;
- e) Welding position;
- f) Preheating;
- g) Welding technique and sequence;
- h) Electrodes, filler materials, flux and shielding gas;
- j) Electrodes, or filler material size, or interpass, temperature or both;
- k) Electrical characteristics and welding speed;

- m) Post-weld heat treatment (temperature, time at temperature, heating and cooling rates);
- n) Test results; and
- p) Identification of inspecting authority.

21.3 Requalification of Procedure— A new procedure qualification test is required consequent upon a change in any of the following:

- a) Type of steel, subject to relaxation given in 21.1;
- b) Welding process;
- c) A change from a backed weld to an unbacked weld;
- d) Welding position, subject to the extent of qualification given in 21.6;
- e) Any change in preheating or interpass temperature, or post-weld heat treatment, except when preheating is increased by not more than 100°C; and
- f) Type of electrode, filler material, flux or shielding gas.

21.3.1 Any change in the make or size of electrodes or filler material shall be reported to the purchaser, but this will not necessarily result in requalification.

21.3.2 In the absence of a change in any of the above items, the qualification of a procedure shall remain in force indefinitely.

21.4 Types of Test Joint — The joint used for a procedure qualification test shall be representative of that to be employed in production. As it is normally impracticable to use actual production castings for this purpose, the test joint may be made between two cast plates or two cast pipes according to which are most representative of the production work to which the procedure being qualified is to relate. In all cases the material for the test pieces shall be made by the same casting process and be of the same type of steel as those used for production work (*see also* 21.1 and Appendix A).

21.4.1 For procedure qualification purposes, a test joint shall be made for one or more of the following types of joint or weld, as stated in the enquiry and/or as agreed to at the time of the order:

- a) A butt joint (plate and/or pipe),
- b) A fillet weld (plate), and
- c) A branch connection (pipes).

21.5 Position

21.5.1 Butt Joint or Fillet Weld Between Plates — A test joint shall be made in each of the following welding positions that is to be used in production:

- a) Flat,
- b) Horizontal-vertical,
- c) Vertical, and
- d) Overhead.

Qualification under (c) includes qualification under (a) and qualification under (d) qualifies the procedure for use in all positions.

NOTE — Welding position is not an essential variable for branch connections.

21.5.2 Butt Joint Between Pipes — A test joint shall be made with the pipes in one or more of the following positions according to which is most representative of production conditions:

- a) Horizontal rotating,
- b) Vertical fixed,
- c) Horizontal fixed, and
- d) 45° to horizontal fixed.

Qualification under (c) includes qualification under (a) and qualification under (d) includes qualification under (a) and (b).

21.6 Pipe Diameter for Butt Joints or Branch Connections — A test on pipe or branch pipe of outside diameter D shall qualify for diameters in the range $0.5D - 1.5D$.

21.7 Tests

21.7.1 Butt Joints Between Plates or Pipes

21.7.1.1 Non-destructive examination — All test joints shall be visually examined. If found to be acceptable and if radiography is to be used for the examination of production work, the test joints shall then be radiographed before the cutting of test specimens. Radiography shall be carried out in accordance with the requirements of either IS:1182-1967* or IS:4853-1968† using the same technique as that to be used for production work.

The standard of acceptance for each method of examination shall be that determined in accordance with the requirements of 19.

*Recommended practice for radiographic examination of fusion welded butt joints in steel plates (first revision).

†Recommended practice for radiographic examination of fusion welded circumferential joints in steel pipes.

21.7.1.2 Transverse tensile test — Transverse tensile test specimens shall be machine cut from each test joint to the dimensions specified in IS : 3600-1966*. The number of test required to qualify a procedure for various thickness ranges shall be as shown in Table 2. If a backing strip has been used, it shall be removed prior to testing.

The tensile strength of specimens when tested in accordance with the requirements of IS : 1608-1960† shall be at least equal to the specified minimum tensile strength for the casting material.

TABLE 2 TYPE AND NUMBER OF TEST SPECIMENS AND RANGE OF THICKNESSES QUALIFIED (PROCEDURES) QUALIFICATIONS

THICKNESS, <i>t</i> , OF TEST PLATE OR PIPE AS WELDED mm	RANGE OF THICKNESSES QUALIFIED		TYPE AND NUMBER OF TEST REQUIRED*			
	Min mm	Max mm	Reduced Section Tension	Side Bend	Face Bend	Root Bend
1.5 to 10 including	1.5	2t†	2	—	2	2
Over 10, under 20	5	2t	2	—	2	2
20 and over	5	2t	2	4	—	—

*Either the face and root bend tests or the side bend tests may be used for thicknesses from 10 to 20 mm.

†The maximum thickness qualified with pipe smaller than 125 mm is two times the thickness of the pipe but not more than 20 mm.

21.7.1.3 Side bend test — Side bend test specimen shall be machine cut from each test joint to the dimensions specified in IS : 3600-1966*. The number of tests required to qualify a procedure for various thickness ranges shall be as shown in Table 2. If a backing strip has been used, it shall be removed prior to testing. The specimen shall be tested in accordance with the requirements of IS : 3600-1966* by bending it through at least 90° round a former of a diameter equal to four times the thickness of the specimen. When the parent metal is incapable of withstanding this test, the former diameter and angle of bend should be modified accordingly. After bending, the specimen shall show no signs of failure, although slight premature tearing at the edges of the specimen need not be considered as cause for rejection.

21.7.1.4 Face and root bend test — Face and root bend test specimens shall be machine cut from each test joint to the dimensions specified in IS : 3600-1966*. The number of tests required to qualify a procedure for various thickness ranges shall be as shown in Table 1. Weld reinforcement and backing strip, if any, shall be removed flush with the surface of the

*Code of procedure for testing of fusion welded joints and weld metal in steel. (Since revised and split into various parts).

†Method for tensile testing of steel products other than sheet, strip, wire and tube. (Since revised).

specimen. If a recess strip is used, this surface of the specimen may be machined to a depth not exceeding the depth of the recess to remove the strip. The specimen shall be bent with a jig in accordance with IS : 3600-1966*. Face bend specimens shall be placed such that the face surface becomes the convex side of the bend specimen. In the case of the root bend test the specimens shall be placed such that the root of the weld becomes the convex side of the bend specimen. The specimen shall be bent until the curvature of the specimen is such that 0.8 mm diameter wire cannot be passed between the curved portion of the male member of the jig and the specimen. The diameter of the former shall be equal to four times the thickness of the specimen.

When the parent metal is incapable of withstanding this test, the former diameter and the angle of bend shall be modified accordingly. After bending the specimen shall be examined for the appearance of opened out defects. Any specimen having any such open defects exceeding 3 mm measured in any direction shall be considered as having failed. Cracks occurring on the corners of the specimen during bending shall be disregarded.

21.7.1.5 Macro-examination — Each test joint shall be sectioned at three places for macro-examination. These sections shall be prepared for macro-etching and etched to give a clear indication of the weld structure. The standard of acceptance shall be determined in accordance with the requirements of 19.

21.7.2 Fillet Welds Between Plates and Branch Connections Between Pipes

21.7.2.1 Visual examination — All test joints shall be visually examined, the standard of acceptance being that determined in accordance with the requirements of 19.

21.7.2.2 Macro-examination — Each test joint shall be sectioned at three places for macro-examination. These sections shall be prepared for macro-etching and etched to give a clear indication of the weld structure. The standard of acceptance shall be that determined in accordance with the requirements of 19.

21.7.3 Hardness Survey for All Test Joints — A hardness survey shall be conducted across a cross section of the test weld and the results shall be recorded for comparison with results of hardness surveys on production welds when required. The method of hardness testing shall be in accordance with IS : 1501-1968†.

21.7.4 Impact Test — When relevant from the point of view of service conditions, impact tests shall be included in the assessment of the welding

*Code of procedure for testing of fusion welded joints and weld metal in steel. (Since revised and split into various parts).

†Method for Vickers hardness test for steel (first revision).

procedure. The number of test specimens, position of notches and impact values to be obtained shall be mutually agreed between the manufacturer and the purchaser. The method of testing shall be in accordance with IS : 3600-1966*.

21.7.5 Repeat Tests — If any of the above tests show that the welds do not meet the required standard, two further test joints shall be made and the tests repeated. If either of these additional test joints does not meet the required standard, the welding procedure shall not be regarded as capable of meeting the requirements of this standard without modification.

22. WELDER QUALIFICATION

22.1 General — Welders employed on welding castings in accordance with this standard shall have been successfully tested by the manufacturer to the satisfaction of an inspecting authority which shall be given the opportunity of witnessing the tests. In all cases, complete records of such tests shall be available for inspection.

22.1.1 The welder who satisfactorily completes the procedure qualification tests is thereby exempt from undergoing separate welder qualification tests involving the same range of procedures.

22.1.2 A welder's qualification to a particular procedure shall remain valid provided that it can be shown that the welder has, subsequent to the test, been employed with reasonable continuity on that procedure and has continued to produce satisfactory welds as verified by non-destructive examination. Requalification shall be required if:

- a) during the preceding six months or more the welder has not been engaged in welding to this procedure, or
- b) there is some specific reason to question the welder's ability, or
- c) it is necessary to requalify the welding procedure, unless the change concerns only the preheating temperature or post-weld heat treatment.

22.1.3 It is recommended that welder qualification tests witnessed and accepted by one inspecting authority should be accepted by other inspecting authorities so long as the welder remains in the employment of the same manufacturer.

22.2 Types of Test Joint — The joint used for a welder qualification test shall be representative of that to be employed in production. As it is normally impracticable to use actual production castings for this purpose, the test joint may be made between two cast plates or two cast pipes according to which are most representative of the production work to

*Code of procedure for testing of fusion welded joints and weld metal in steel. (Since revised and split into various parts).

which the welder being qualified is to relate. In all cases the material for the test pieces shall be made by the same casting process and be of the same type of steel as those used for production work (see Appendix A).

22.2.1 For welder qualification purposes, a test joint shall be made for one or more of the following types of joint or weld as stated in the enquiry and/or as agreed to at the time of the order:

- a) A butt joint (plate and/or pipe),
- b) A fillet weld (plate), and
- c) A branch connection (pipes).

Qualification under (a) includes qualification under (b).

22.3 Position

22.3.1 Butt Joint or Fillet Weld Between Plates — A test joint shall be made for each welding position that is to be used in production (flat, horizontal-vertical, vertical or overhead).

Qualification in the horizontal-vertical and vertical positions also qualifies for welding in the flat position. Qualification in the vertical and overhead positions also qualifies for welding in the flat and horizontal-vertical positions.

22.3.2 Butt Joint Between Pipes — A test joint shall be made with the pipes in one or more of the following positions according to which is most representative of production conditions:

- a) Horizontal rotating,
- b) Vertical fixed,
- c) Horizontal fixed, and
- d) 45° to horizontal fixed.

22.3.2.1 Qualification under (c) includes qualification under (a) and qualification under (d) qualifies for welding in all positions.

22.3.2.2 Qualification on a butt joint between pipes also qualifies for welding butt joints and fillet welds between plates for the same welding position.

22.3.2.3 Welding position is not an essential variable for branch connections.

22.4 Pipe Diameter for Butt Joints or Branch Connections — A test on pipe or branch pipe of outside diameter D shall qualify for diameters in the range $0.5D - 1.5D$.

22.5 Tests

22.5.1 Butt Joints Between Plates or Pipes

22.5.1.1 Non-destructive examination — All test joints shall be visually examined. If found to be acceptable and if radiography is to be used for the examination of production work, the test joints shall then be radiographed before the cutting of test specimens. Radiography shall be carried out in accordance with the requirements of either IS : 1182-1967* or IS : 4853-1968† using the same technique as that to be used for production work.

The standard of acceptance for each method of examination shall be that determined in accordance with the requirements of 19.

22.5.1.2 Side bend test — Side bend test specimens shall be machine cut from each test joint to the dimensions specified in IS : 3600-1966‡. The number of tests required to qualify a procedure for various thickness ranges shall be as given in Table 3. If a backing strip has been used, it shall be removed prior to testing.

TABLE 3 TYPE AND NUMBER OF TEST SPECIMENS AND RANGE OF THICKNESSES QUALIFIED (WELDER'S PERFORMANCES)

THICKNESS t , OF TEST PLATE OR PIPE AS WELDED mm	RANGE OF THICKNESS QUALIFIED		TYPE AND NUMBER OF TESTS REQUIRED*		
	Min mm	Max mm	Side Bend	Face Bend	Root Bend
1.5 to 10 including	1.5	$2t$	—	1	1
Over 10, under 20†	5	$2t$	—	1	1
Over 10, under 20†	5	$2t$	2	—	—
20 and over	5	Max to be welded	2	—	—

*A total of four specimens are required to qualify for horizontal-fixed position.

†Either the face and root bend tests or the side bend tests may be used for thicknesses from 10 to 20 mm.

Each specimen shall be tested in accordance with the requirements of IS : 3600-1966‡ by bending it through at least 90° round a former of a diameter equal to four times the thickness of the specimen. When the

*Recommended practice for radiographic examination of fusion welded butt joints in steel plates (*first revision*).

†Recommended practice for radiographic examination of fusion welded circumferential joints in steel pipes.

‡Code of procedure for testing of fusion welded joints and weld metal in steel. (Since revised and split into various parts).

parent metal is incapable of withstanding this test, the former diameter and angle of bend should be modified accordingly.

After bending, the specimen shall show no signs of failure, although slight premature tearing at the edges of the specimen need not be considered as cause for rejection.

22.5.1.3 Face and root bend tests — Face and root bend test specimens shall be machine cut from each test joint to the dimensions specified in IS : 3600-1966*. The number of tests required to qualify a procedure for various thickness ranges shall be as shown in Table 2. Weld reinforcement and backing strip, if any, shall be removed flush with the surface of the specimen. If a recess strip is used, this surface of the specimen may be machined to a depth not exceeding the depth of the recess to remove the strip. The specimen shall be bent with a jig in accordance with IS : 3600-1966*. Face bend specimens shall be placed such that the face surface becomes the convex side of the bend specimen. In the case of the root bend test the specimens shall be placed such that the root of the weld becomes the convex side of the bend specimen. The specimen shall be bent until the curvature of the specimen is such that, 8 mm diameter wire cannot be passed between the curved portion of the male member of the jig and the specimen. The diameter of the former shall be equal to four times the thickness of the specimen.

When the parent metal is incapable of withstanding this test, the former diameter and the angle of bend shall be modified accordingly. After bending the specimen shall be examined for the appearance of opened out defects. Any specimen having any such opened defects exceeding 3 mm measured in any direction shall be considered as having failed. Cracks occurring on the corners of the specimen during bending shall be disregarded.

22.5.1.4 Macro-examination — Each test joint shall provide two weld cross sections for macro-examination. These sections shall be prepared for macro-etching and etched to give a clear indication of the weld structure.

The standard of acceptance shall be that determined in accordance with the requirements of 19.

25.5.2 Fillet Weld Between Plates and Branch Connections Between Pipes

22.5.2.1 Visual examination — All test joint shall be visually examined, the standard of acceptance being that determined in accordance with the requirements of 19.

*Code of procedure for testing of fusion welded joints and weld metal in steel. (Since revised and split into various parts).

22.5.2.2 Macro-examination — Each test joint shall be sectioned at three places for macro-examination. These sections shall be prepared for macro-etching and etched to give a clear indication of the weld structure.

The standard of acceptance shall be that determined in accordance with the requirements of 19.

22.5.3 Repeat Test — If any of the above tests show that the welds do not meet the required standard, two further test joints shall be made and the tests repeated. If either of these additional test joints does not meet the required standard, the welder shall not be regarded as capable of meeting the requirements of this standard without further training.

APPENDIX A

(Clauses 5.1.4, 7.3, 8.1, 8.3, 15.5, 17.1, 19.1, 21.4 and 22.2)

ITEMS FOR AGREEMENT BETWEEN THE CONTRACTING PARTIES

A-1. The following, where applicable, are the items for agreement between the contracting parties:

- a) Flux/electrode wire combinations for submerged-arc welding (5.1.4).
- b) Acceptability of fusion faces when non-destructive testing is used (7.3).
- c) Sealing-off of filamentary shrinkage (7.3).
- d) Type of backing strip (8.1).
- e) Use of copper backing bar (8.3).
- f) Use of alternative methods of heating for post-weld heat treatment (15).
- g) Alternative method of stress relief (17).
- h) Inspection of completed welds (19).
- j) Types of test joint for procedure qualification (21.4).
- k) Types of test joint for welder qualification (22.2).

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Members

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SHRI B. HILL

SHRI H. S. RAO (*Alternate*)

SHRI V. G. JAGANNATH

SHRI R. VISVANATHAN (*Alternate*)

SHRI S. V. NADKARNI

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BUREAU OF INDIAN STANDARDS

Headquarters:

Manak Bhavan, 9 Bahadur Shah Zafar Marg, NEW DELHI 110002

Telephones : 331 01 31, 331 13 75

Telegrams : Manaksanatha
(Common to all offices)

Regional Offices:

	Telephones
Central : Manak Bhavan, 9 Bahadur Shah Zafar Marg, NEW DELHI-110002	[331 01 31 331 13 75
*Eastern : 1/14 C.I.T. Scheme VII M, V. I. P. Road, Maniktola, CALCUTTA 700054	36 24 99
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